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RESERVE STOCKS OF GRAIN

Research Status Report Number 1

Description of the Price Bounds Model

By

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Economic Research Service
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COMMODITY
ECONOMICS DIVISION

ECONOMIC RESEARCH SERVICE U.S. DEPARTMENT OF AGRICULTURE

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The purpose of this report is (a) to give a status report on our research on reserve stocks of grain, and (b) to outline our plans for additional research. We hope that this report will serve as a stimulant to other analysts interested in the reserve stocks issue and that they will feel free to exchange ideas with the authors about the ideas contained in this report and related issues.

The wheat stocks simulation model reported here is a prototype used as a first step in our overall research program on reserve stocks. Additional work is planned using this model. Based on what we learn from this prototype, we plan to develop a larger model containing food grains, feed grains, and soybeans.

This report contains the following items:

A. A description of the basic wheat stocks simulation model,

B. Two sets of results using the simulator,

C. Plans for additional use of the wheat reserve stocks simulator.

[1/] Agricultural economists, Commodity Economics Division, ERS, U.S. Dept. of Agriculture stationed at Purdue University. David Banker, research associate in agricultural economics at Purdue assisted with the model development and analysis.

The Wheat Reserve Stocks Simulator

The wheat reserve stocks simulator contains a very simple abstraction of the wheat market in the United States.[2/] The model contains a linear supply function and a linear demand function that becomes perfectly elastic at a wheat price of $0.75. The total demand function is segmented into the domestic demand curve and the export demand curve.

The wheat supply and demand equations are shown in figure 1. These equations are synthesized for the 1974 to 1980 period, i.e., the original equations which were estimated econometrically were adjusted for structural change so that they would be more realistic for the 1974-1980 period.

In the simulator production is a function of price the previous year, yield, and government programs. For the purposes of figure 1 it is assumed that there is no government acreage control program for wheat. Yield is assumed to increase from 32.2 bushels per harvested acre in 1974 to 35.8 in 1980, in line with ERS projections. Yield also contains a random disturbance term estimated from historical wheat yields. The equations for the two supply curves shown in figure 1 are:

$$S_{74} = 1406.5 + 163.69(P) + E$$

$$S_{80} = 1564.7 + 182.10(P) + E$$

where

S_{74} is the supply of wheat assuming average 1974 yield (million bu.),

S_{80} is the supply of wheat assuming average 1980 yield (million bu.),

[2/] The simulation model is similar to the model used by Tweeten, Kalbfleisch and Lu [2].

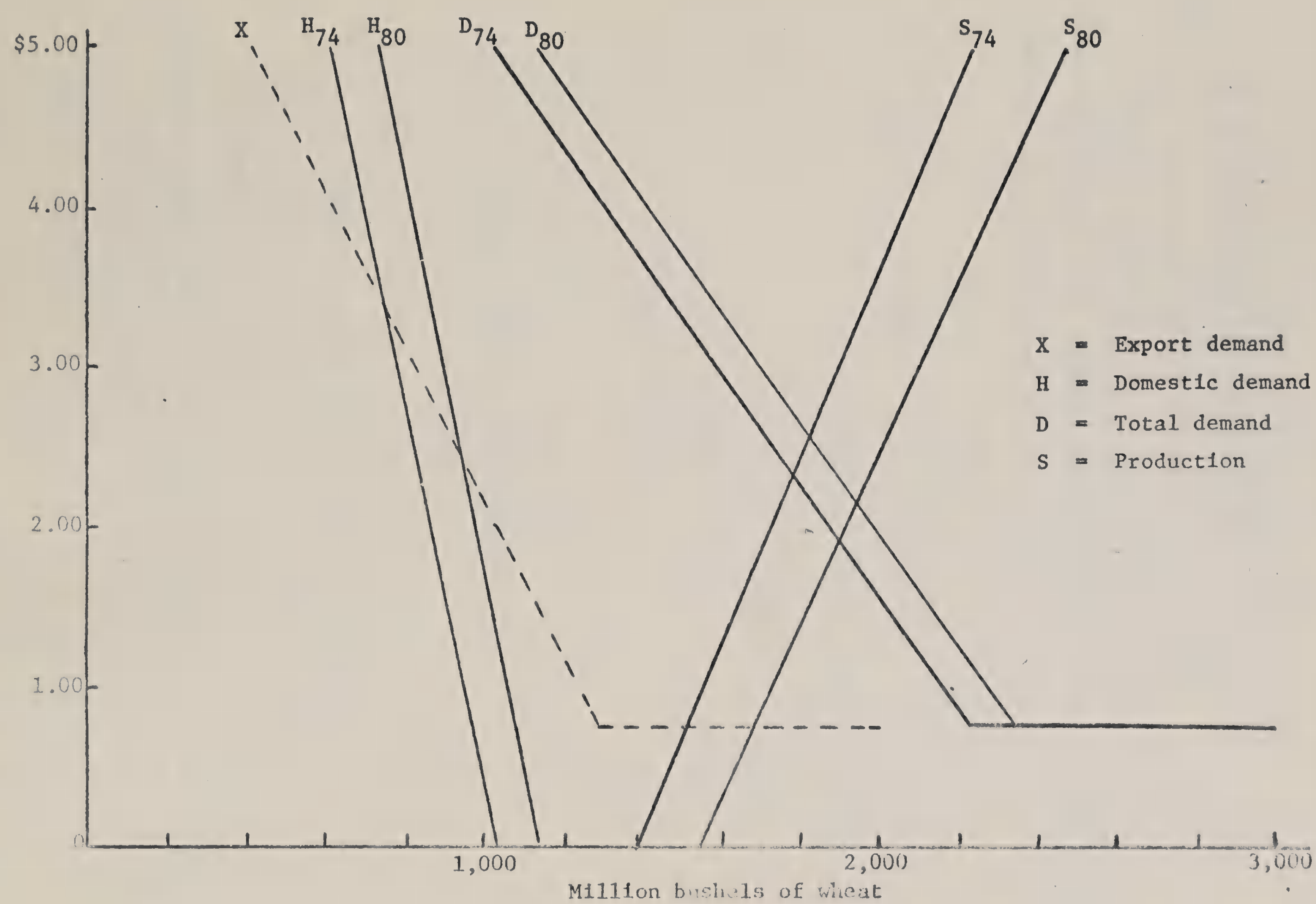


Figure 1. Supply and demand for wheat, U.S.

E is normally distributed with $\bar{E} = 0$, and

P is price lagged one year (dollars).

The supply functions for 1975 through 1979 lie between S_{74} and S_{80}.

Demand is divided into two components, domestic and export. A time trend is included in the domestic demand equation but not in the export equation. The equations for the demand curves in figure 1 are:

$$H_{74} = 1030 - 83.3(P)$$

$$H_{80} = 1150 - 83.3(P)$$

$$X = 1427.0 - 202.4(P) + R \text{ for } P \geq 0.75$$

$$X = \infty \text{ for } P < 0.75$$

$$D_{74} = H_{74} + X$$

$$D_{80} = H_{80} + X$$

where

H_{74} is domestic demand in 1974 (million bu.),

H_{80} is domestic demand in 1980 (million bu.),

X is export demand (million bu.),

D_{74} is domestic demand in 1974 (million bu.),

D_{80} is domestic demand in 1980 (million bu.), and

R is normally distributed with $\bar{R} = 0$ and $S_R = 150$.

Since the export equation and the supply equations contain random disturbance terms, there are an infinite number of export and supply curves that could be drawn in figure 1. The curves shown are the mean of all price-quantity relations.

The export demand function is made perfectly elastic at $0.75 as a procedural device to eliminate the approximately one percent of the observations that combine very high production with very low export demand. These could generate a market price below $0.75 given the linear functions. This adjustment has virtually no affect on the overall results.

Figure 2 shows the 1974 supply and demand curves along with two standard deviations above and below the export demand curve, total demand curve and supply curve.

The time trend built into the domestic consumption function is more than offset by the time trend in yield. Thus the equilibrium price decreases over time. A time trend for exports could more than offset this difference, and cause price to rise over time, but no time trend for exports was used in this model.

The Free Market Simulation

The purpose of the free market simulation is to show how the model performs with no government controls. The destabilizing effects of the stochastic yields and exports and the lagged production response to price are allowed to operate unchecked. This free market simulation is the base against which other solutions are compared.

Using the supply and demand relations discussed above, the simulator is run for the years 1974 through 1980. This 7-year sequence is simulated 1,000 times assuming no government acreage control programs or stocks policies. The only linkage between one year and the next is provided by price which is a lagged variable in the supply equation.

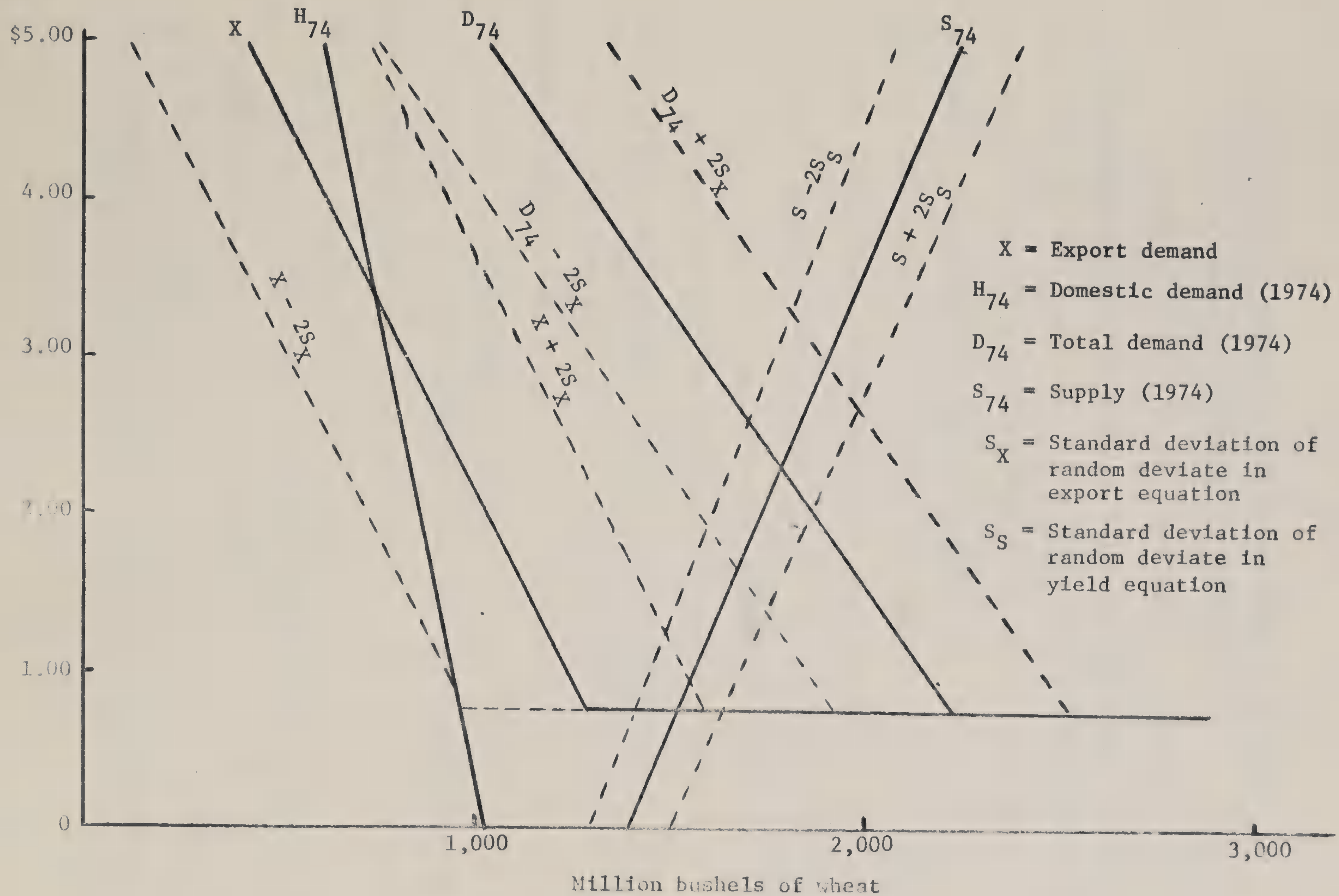


Figure 2. Supply and demand for wheat (plus and minus two standard deviations), U.S.

Table 1 shows a summary of results for each of the seven years and for the seven-year period. The 1973 market price for wheat used in the 1974 supply function is $2.93. The summary of results for 1974 show 59 million acres of wheat harvested in all 1,000 solutions. The average yield is 32.18 bushels per acre, but over the 1,000 solutions the yield varies from 28.49 bushels to 36.60 bushels and has a standard deviation of 1.2 bushels. Because of the yield variation, total production also varies around the mean of 1.9 billion bushels. One billion bushels of the 1974 crop are exported and 0.9 billion bushels are used domestically on the average at a market clearing price of $2.01. The coefficient of variation on both yields and production is 4 percent, while the coefficient of variation on exports is higher at 7 percent. The combined effect of the random deviation in yields and exports shows up in the coefficient of variation for export sales and price. Over the 1,000 solutions wheat price ranges from $0.75 to $3.81 with a coefficient of variation of 28 percent.

Overall the $2.93 lagged price stimulates relatively high production in 1974 leading to a lower market price in most solutions for the 1974 marketing year. Yield and export variations, however, create a wide range of prices and value of export sales.

Results over the 7 years demonstrate the cobweb-type response that is built into the simulation model. The 1973 wheat price ($2.93), used in the 1974 production equation, is relatively high causing a large quantity of wheat to be produced. Consequently, the average 1974 market price in the simulator is low ($2.01) resulting in a smaller acreage

Table 1. Summary of results from the wheat reserve stocks simulation run assuming no Government acreage control program or stocks policies, U.S., 1974 to 1980 and 1974-1980 summary.

Item	Unit	Mean	Standard deviation	Coefficient of variation	Range of values	
					Minimum	Maximum
			1974			
Acres harvested	1,000 acres	58,612	0	0.0	58,612	58,612
Yield	bushel	32.18	1.20	.04	28.49	36.60
Production	mil. bushel	1,886	70	.04	1,670	2,145
Domestic use	mil. bushel	863	47	.05	713	968
Exports	mil. bushel	1,023	68	.07	753	1,216
Export sales	mil. dols.	2,063	628	.30	565	4,076
Price	dollars	2.01	.56	.28	.75	3.31
Value of production	mil. dols.	3,769	1,008	.27	1,386	6,748
			1975			
Acres harvested	1,000 acres	53,916	2,855	.05	47,523	63,064
Yield	bushel	32.79	1.26	.04	28.52	37.04
Production	mil. bushel	1,768	116	.07	1,420	2,160
Domestic use	mil. bushel	841	55	.07	671	988
Exports	mil. bushel	927	95	.10	589	1,194
Export sales	mil. dols.	2,309	626	.27	610	4,467
Price	dollars	2.50	.66	.26	.75	4.55
Value of production	mil. dols.	4,379	1,024	.23	1,354	7,468
			1976			
Acres harvested	1,000 acres	56,439	3,372	.06	47,523	66,845
Yield	bushel	33.33	1.28	.04	29.55	37.51
Production	mil. bushel	1,881	134	.07	1,526	2,318
Domestic use	mil. bushel	889	57	.06	707	1,008
Exports	mil. bushel	992	105	.11	660	1,319
Export sales	mil. dols.	2,142	653	.30	597	4,208
Price	dollars	2.18	.68	.31	.75	4.36
Value of production	mil. dols.	4,041	1,115	.28	1,442	7,103
			1977			
Acres harvested	1,000 acres	54,799	3,462	.06	47,523	65,869
Yield	bushel	34.04	1.24	.04	29.86	37.83
Production	mil. bushel	1,865	136	.07	1,475	2,345
Domestic use	mil. bushel	898	58	.07	714	1,028
Exports	mil. bushel	967	105	.11	643	1,257
Export sales	mil. dols.	2,204	650	.30	613	4,170
Price	dollars	2.30	.70	.30	.75	4.51
Value of production	mil. dols.	4,233	1,126	.27	1,434	7,3[illegible]

Table 1. continued

Item	Unit	Mean	Standard deviation	Coefficient of variation	Range of values	
					Minimum	Maximum
			1978			
Acres harvested	1,000 acres	55,428	3,564	.06	47,523	66,668
Yield	bushel	34.62	1.24	.04	30.84	38.69
Production	mil. bushel	1,919	141	.07	1,542	2,515
Domestic use	mil. bushel	930	59	.06	753	1,048
Exports	mil. bushel	989	110	.11	666	1,331
Export sales	mil. dols.	2,137	673	.32	564	4,405
Price	dollars	2.18	.70	.32	.75	4.29
Value of production	mil. dols.	4,122	1,177	.29	1,364	7,450
			1979			
Acres harvested	1,000 acres	54,809	3,582	.07	47,523	65,524
Yield	bushel	35.29	1.26	.04	31.24	40.26
Production	mil. bushel	1,934	147	.08	1,528	2,350
Domestic use	mil. bushel	948	60	.06	749	1,068
Exports	mil. bushel	986	113	.11	683	1,354
Export sales	mil. dols.	2,131	660	.31	580	4,372
Price	dollars	2.19	.72	.33	.75	4.57
Value of production	mil. dols.	4,165	1,185	.28	1,441	7,797
			1980			
Acres harvested	1,000 acres	54,853	3,663	.07	47,523	66,978
Yield	bushel	35.80	1.21	.03	32.34	39.81
Production	mil. bushel	1,963	147	.07	1,557	2,444
Domestic use	mil. bushel	971	60	.06	773	1,088
Exports	mil. bushel	992	113	.11	613	1,370
Export sales	mil. dols.	2,114	668	.32	617	4,017
Price	dollars	2.16	.72	.33	.75	4.53
Value of production	mil. dols.	4,167	1,210	.29	1,486	7,516
			1974-1980[1/]			
Acres harvested	1,000 acres	55,551	3,483	.06	47,523	66,978
Yield	bushel	34.01	1.75	.05	28.49	40.26
Production	mil. bushel	1,888	142	.08	1,420	2,515
Domestic use	mil. bushel	906	71	.08	671	1,088
Exports	mil. bushel	982	106	.11	589	1,370
Export sales	mil. dols.	2,157	656	.30	[illegible]	[illegible]
Price	dollars	2.22	.69	.31	.75	4.57
Value of production	mil. dols.	4,125	1,136	.28	1,354	7,797

1/ Computed over all 7,000 observations (1,000 iterations over 7 years).

being planted in 1975. The relatively short production in 1975 leads to a higher price in 1975, which in turn leads to an increase in production in 1976. As 1980 is approached, the price cycles and the cobweb effect are minimal.

The summary of results for the 7-year period shows relatively small coefficients of variation for acres harvested and yield. The coefficient of variation for export sales, price and gross income are relatively high (in the 30 percent range) because of the interactions of the random disturbances on yield and quantity exported as well as the year to year changes in acres harvested and domestic demand.

Given the supply and demand equations in figure 1 plus the random disturbances associated with yields and exports, the results show a wide range in outcomes of production, domestic use, exports, and value of production. If these are reasonable abstractions of real world conditions there would probably be pressure on the government from producers and from consumers to reduce fluctuations in prices and incomes.

The Bounded Price Simulation

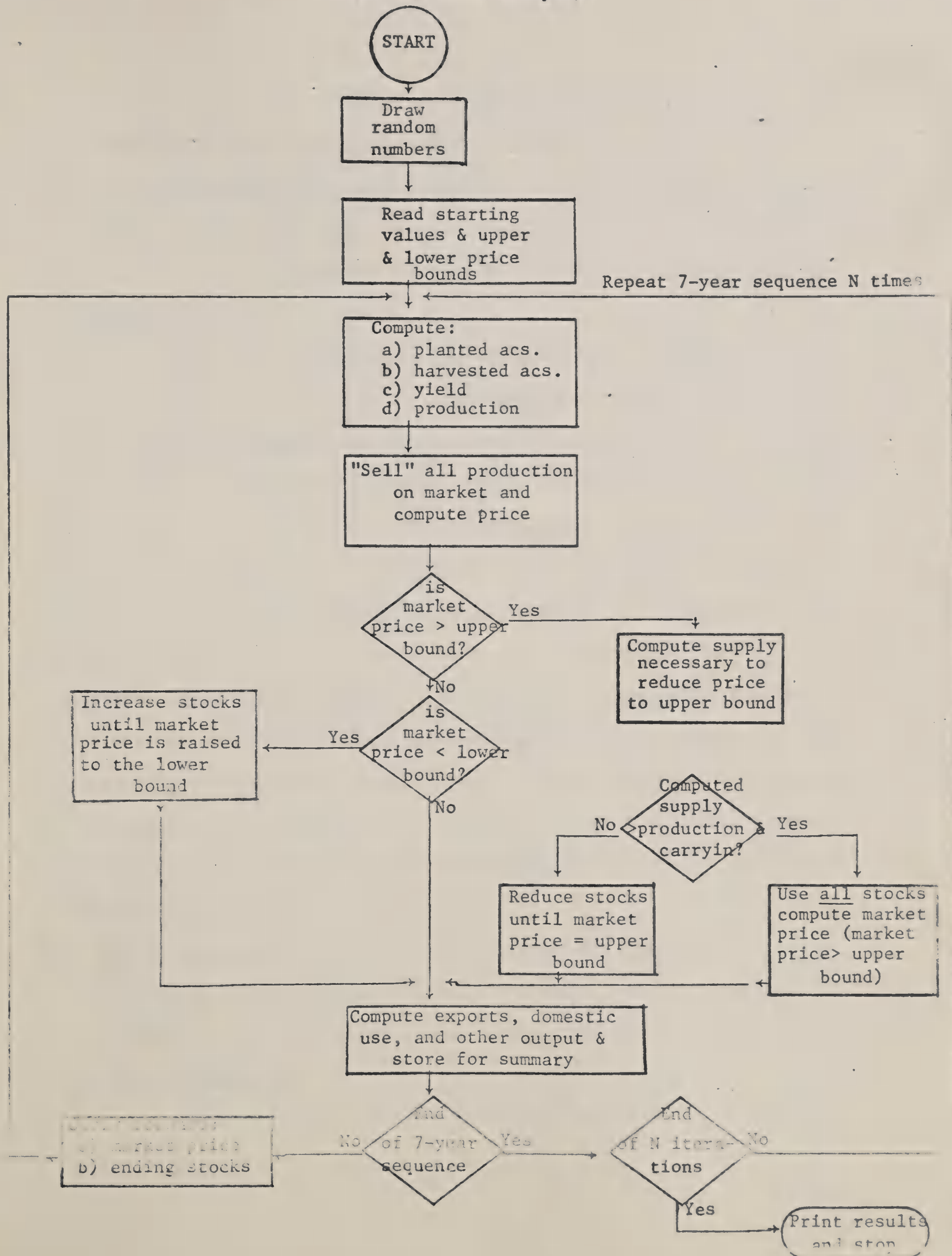
A second run of the simulator is made assuming that a reserve stocks program is used to modify price fluctuations. If the market price falls below some lower bound the government purchases the quantity necessary to make supply equal demand at the lower bound price. If the market price exceeds the upper bound the government sells stocks, if available, until supply equals demand at the upper bound price. If

stocks are inadequate to hold the market price at the upper bound, all stocks are sold and the price advances above the upper bound.[3/]

The flow chart in figure 3 shows the sequence of operations for the case where upper and lower bounds are placed on wheat price. The simulation process is started by drawing a large number of random numbers and reading in the starting parameters. Computations are then made that lead to a quantity produced. That quantity produced is then put into the aggregate demand equation and a market price is computed. If the market price exceeds the upper bound on price, a sequence of steps are taken to sell stocks and compute a new adjusted market price. If the market price is initially below the lower bound, the government purchases stocks in large enough quantity so that supply will equal demand at the lower bound. If the initial market price falls between the upper and lower bounds, no stocks activity is initiated. After all stocks decisions are made, the simulator computes exports, domestic use and other output and stores the results for later summary. The computed market price and ending stocks information are then carried forward to initiate the second year of the 7-year sequence. The 7-year sequence is replicated a large number of times (1,000 replications were used in these two examples) and at the end of the replications results are summarized and printed.

[3/] The size of the reserve stock is assumed to not affect the market price when the price is between the upper and lower bounds, i.e., participants in the market are assumed to have confidence that the stocks management agency will follow the rules as specified in the simulation. This is a controversial assumption. Opponents of a publicly controlled reserve stock say there is no way to prevent the reserve stock from depressing prices.

Figure 3. Flow Chart of Wheat Stocks Management Simulation Model (Price Bounds Example).



In the free market simulation, run with no bounds on price, the average wheat price over the 7 years and the 1,000 replications is $2.22. For this simulation, upper and lower price bounds are set at $0.50 above and $0.50 below the average market price so that for the 7-year period the price at which stocks are sold is $2.72 and the price at which stocks are purchased is $1.72.

The results of the bounded price simulation are summarized in table 2. Compared with the results from the free market simulation, there is virtually no change in <u>average</u> production, domestic use, exports, market price, and gross income. The variation in these items, however, is reduced significantly. The variation in price, as measured either by the standard deviation or the coefficient of variation, is reduced 39 percent by using the specified price bounds. The variation in harvested acres is reduced by one-third, while the variation in production is reduced 25 percent. The variation in bushels exported is reduced only 9 percent. This small reduction is explained by the relatively large portion of export variation due to the random deviate--deviation that is independent of price variation.

Analysis of the summary of results for each of the 7 years shows that the cobweb effect still exists but is dampened relative to the free market simulation.

This simulation is started with a beginning inventory in 1974 of 170 million bushels of wheat. By 1980 the average carryout increases to 202 million bushels. Supply shifts to the right faster than demand in this model, causing the market price to trend downward, and since the upper and lower price bounds stay constant over time, stocks gradually increase.

Table 2. Summary of results from the wheat reserve stocks simulation run assuming a stocks purchase price of $1.72 and a stocks sale price of $2.72, U.S., 1974-80 summary.[1/]

Item	Unit	Mean	Standard deviation	Coefficient of variation	Range of values	
					Minimum	Maximum
Acres harvested	1,000 acres	55,570	2,317	.04	52,457	64,888
Yield	Bu.	34.01	1.75	.05	28.49	40.26
Production	M. Bu.	1,889	111	.06	1,496	2,355
Domestic use	M. Bu.	904	53	.06	734	1,007
Exports	M. Bu.	985	100	.10	553	1,302
Export sales	M. Dol.	2,196	527	.24	952	4,326
Price	Dol.	2.23	0.42	.19	1.72	4.16
Carryin	M. Bu.	176	107	.61	0	808
Carryout	M. Bu.	180	123	.68	0	836
Purchases	M. Dol.	39	100	2.54	0	867
Sales	M. Dol.	50	128	2.56	0	1,007
Storage cost	M. Dol.	27	16	.61	0	121
Value of production	M. Dol.	4,184	696	.17	2,814	7,371
Frequency of zero stocks	Percent	8.57				

[1/] Computed over all 7,000 observations (1,000 iterations over 7 years).

The stocks management activity looses money in the typical year over the 7 years and the 1,000 iterations. For the average year costs and returns to the storage activity are:

Million dollars	
50	Sales (from table 2)
8	Increase in inventory [(180 - 176) × $1.72]
-39	Purchases (from table 2)
-27	Storage costs @ .15 per bushel (from table 2)
-24	8 percent interest charged on average inventory (178 million bushel) × purchase price ($1.72)
-32	

The net cost of managing the stocks activity for the typical year is $32 million plus administrative and transportation costs. Costs would be much higher in years when large purchases would be made but there could be net profits in years with large sales. For comparison, from 1961 to 1973 when CCC owned wheat stocks went from 1.2 billion bushels down to nothing, the average annual expenditure on loans and purchases for wheat and wheat products was $521 million; storage and handling, $75 million; and transportation and other expenditures $94 million. Sales and loan repayments by farmers brought in $736 million.

The average level of stocks in this simulation (about 180 million bushels of wheat) is considerably smaller than is being suggested by many recent reserve proposals. But over the 7,000 observations the frequency of the ending inventory being zero is 8.6 percent--probably too

high to be socially acceptable. If the simulation would have been started with a larger opening stock, the probability of running out in any one year would have decreased.

Thus an important policy question is raised, "How much will it cost to purchase various levels of safety against the probability of running out of stocks?" This question can be examined using the bounded price simulation model. One can view the beginning inventory of stocks in the simulation model as a target level of stocks that the stocks manager will try to average over time.

Alternative target levels of stocks are examined using the simulator. Also, since the standard deviation about the export demand function for the 1974-1980 period is virtually unknown, two levels are examined: S_X = 150 million bushel and S_X = 300 million bushel. Results of seven observations are shown in figure 4. Increased safety (reduction in the frequency of running out of stocks in any year) is obtained by increasing the target stock level. For example, the simulation reported in table 2 was run assuming a standard deviation of the random deviate in the export demand function (S_X) of 150 million bushels, and a beginning inventory (a target stock) of 170 million bushels. As indicated previously, that simulation yields an 8.6 percent probability of having a zero ending inventory in any one year and an average annual cost of $32 million. By raising the beginning inventory (the target stock) to 500 million bushels, the probability of running out of stocks in any one year drops to less than 1 percent, but the average annual cost increases to $120 million (figure 3).

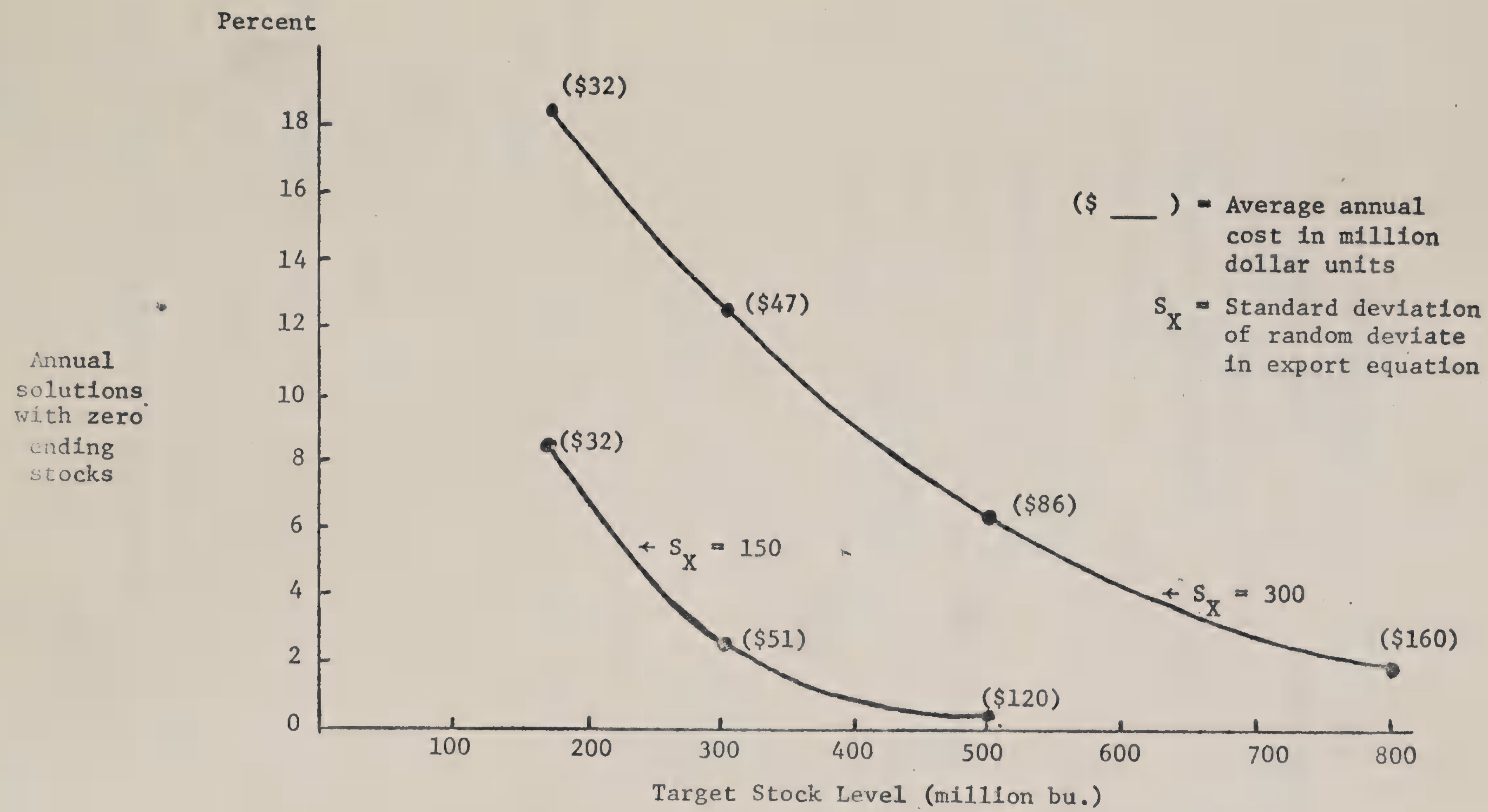


Figure 4. Frequency of running out of reserve wheat stocks and cost associated with various wheat target stock levels, U.S., simulated.

With greater variation in the export equation (S_X = 300 million bushel) it takes a larger reserve stock and increased cost to maintain a specified probability of running out of stocks.

Thus a reserve stocks policy should logically be accompanied by various trade agreements that would tend to reduce year-to-year variation in export demand. Also, a build-up of stocks in importing countries could reduce the variation.

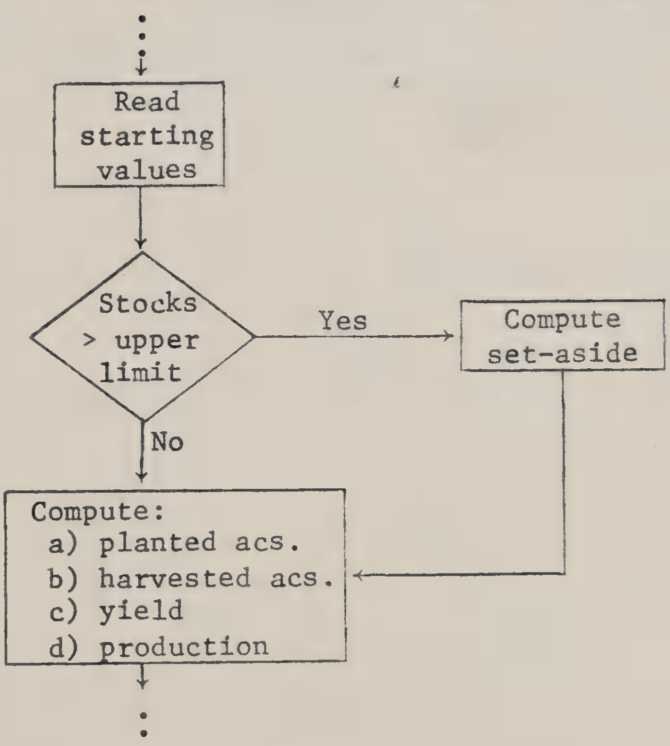
To summarize, these simulations show that a reserve stocks policy can significantly reduce variation in prices and quantities while incurring a relatively small net cost per year. The probability of running out of reserve stocks is reduced if export variability can be reduced with multi-national agreements or by build-up of stocks in importing countries. These conclusions are based upon the assumption that upper and lower bounds can be set with perfect knowledge of the free market equilibrium price over the 7-year period. This assumption will be examined further.

Plans

Current plans for use of the prototype wheat stocks simulation model can be divided into three parts; (1) using the simulator with upper and lower price bounds to examine additional questions, (2) altering the supply and demand conditions of the simulator, and (3) examining storage rules that cannot be stated in a bounded price framework.

The simulator as used in this report and as described in figure 3 can be used to examine several other questions. We have tentative plans to

examine the following: (1) Develop and test a method for setting upper and lower price bounds that are self-correcting if improperly specified, e.g., if the price bounds are set too high and very large quantities of stocks accumulate, an automatic mechanism would be triggered that would lower the upper and lower bounds. The opposite problem of setting the bounds too low would also be examined. (2) Examine the alternative of setting aside wheat land when carryin stocks get too large. Adding the alternative of annual set-aside to the flow chart on figure 3 could be done as follows:



(3) Examine the impact of putting an upper limit on Treasury costs.

(4) Test the implications of wheat stock proposals made by Humphrey [3], Cochrane [1], and McGrory [4].

We plan to examine the implications of greater variation in export demand along with an upward trend in export demand.

We plan also to examine storage rules that cannot be stated in a bounded price framework. One specific example is the storage rule where stocks are a function of supply. This type of storage rule can be used to maximize welfare over time or minimize social cost over time. This would follow up on work done by Gustafson [2] and Tweeten, Kalbfleisch and Lu [5].

Short reports will be prepared on each of these activities as they are completed. We encourage comments on the model and on the results as we progress.

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[5] Tweeten, Luther, Dale Kalbfleisch and Y. C. Lu, "An Economic Analysis of Carryover Policies for the United States Wheat Industry," Oklahoma State University, Agric. Exp. Sta. Tech. Bul. T-132, October 1971.